NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

OPTIMIZING MARINE CORPS PILOT CONVERSION TO THE JOINT STRIKE FIGHTER

by

Shannon V. Holloway

June 2010

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2010	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE Optimizing Marine Corps Pilot Conversion to the Joint Strike Fighter			**5. FUNDING NUMBERS**
6. AUTHOR(S) Holloway, Shannon V.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ________________.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The United States Marine Corps is replacing its fixed wing fighter and attack aircraft with the new F-35 Joint Strike Fighter. Retirement of F/A-18 Hornets and AV-8B Harriers will make their associated military occupational specialties obsolete. The conversion of personnel to the new aircraft must be carefully managed to ensure appropriate manning levels for the Joint Strike Fighter, while maintaining adequate quantities of experienced personnel in the legacy communities. The Deputy Commandant for Aviation manages the manpower requirements to support the new aircraft through boards which select the best qualified applicants for transition and conversion training. Transition or conversion training serves to balance current aviator inventories with future Marine Corps requirements. This thesis presents the Marine Corps Pilot Conversion Analysis Tool which uses an integer linear program to prescribe pilots for accession and conversion to the new aircraft based on military occupational specialty, years of commissioned service, and level of experience. Our analysis shows that the current plan meets the total pilot accession and conversion requirement, but does not select enough junior-ranking officers to maintain the hierarchical structure desired. Further analysis shows that significantly increasing new accessions and conversions of junior officers provides the best pilot-to-billet matches while generating the smallest training flight-hour backlog.

14. SUBJECT TERMS Integer Linear Program, Optimization, Manpower Model, F-35, Joint Strike Fighter, United States Marine Corps			**15. NUMBER OF PAGES** 75
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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OPTIMIZING MARINE CORPS PILOT CONVERSION TO THE JOINT STRIKE FIGHTER

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
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The United States Marine Corps is replacing its fixed wing fighter and attack aircraft with the new F-35 Joint Strike Fighter. Retirement of F/A-18 Hornets and AV-8B Harriers will make their associated military occupational specialties obsolete. The conversion of personnel to the new aircraft must be carefully managed to ensure appropriate manning levels for the Joint Strike Fighter, while maintaining adequate quantities of experienced personnel in the legacy communities. The Deputy Commandant for Aviation manages the manpower requirements to support the new aircraft through boards which select the best qualified applicants for transition and conversion training. Transition or conversion training serves to balance current aviator inventories with future Marine Corps requirements. This thesis presents the Marine Corps Pilot Conversion Analysis Tool, which uses an integer linear program to prescribe pilots for accession and conversion to the new aircraft based on military occupational specialty, years of commissioned service, and level of experience. Our analysis shows that the current plan meets the total pilot accession and conversion requirement, but does not select enough junior-ranking officers to maintain the hierarchical structure desired. Further analysis shows that significantly increasing new accessions and conversions of junior officers provides the best pilot-to-billet matches while generating the smallest training flight-hour backlog.

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DISCLAIMER

The reader is cautioned that the computer programs presented in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logical errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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LIST OF ACRONYMS AND ABBREVIATIONS

API	Aviation preflight indoctrination
BUR	Bottom Up Review
CSC	Command and Staff College
csv	comma separated value
DCA	Deputy Commandant for Aviation
DoD	Department of Defense
EWS	Expeditionary Warfare School
FAA	First Aircraft Arrival
FOC	Full Operational Capability
FRS	Fleet Replacement Squadron
FY	Fiscal Year
IOC	Initial Operational Capability
JAST	Joint Advanced Strike Technology
JSF	Joint Strike Fighter
MAGTF	Marine Air-Ground Task Force
MCTFS	Marine Corps Total Force Structure
MCO	Marine Corps Order
MCPCAT	Marine Corps Pilot Conversion Analysis Tool
MMOA	Officer Assignments, Manpower and Reserve Affairs
MOS	Military Occupational Specialty
NAS	Naval Air Station
PCS	Permanent Change of Station
RFO	Ready for Operation
STOVL	Short Take-Off/Vertical Landing
T/C	Transition and/or Conversion
T/O	Table of Organization
USMC	United States Marine Corps
YCS	Years Commissioned Service

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EXECUTIVE SUMMARY

The United States Marine Corps (USMC) is currently planning to transition from F/A-18 A/C/D Hornets and AV-8B Harriers to the new F-35 Joint Strike Fighter (JSF). The Deputy Commandant for Aviation (DCA) manages manpower requirements to support the new aircraft through boards which select the best qualified applicants for transition and/or conversion (T/C) training. These boards serve to balance current aviator inventories with future Marine Corps requirements.

Transition training is defined as syllabus instruction designed for pilots to change aircraft type. Conversion training is defined as syllabus instruction designed for pilots to change from one model aircraft to another within a specific aircraft type; e.g., CH-46 to CH-53 or EA-6B to F/A-18, or to change to a new series of aircraft that has significantly different aircraft or weapons systems characteristics.

In the current case, two aircraft and their associated military occupational specialties will become obsolete. The conversion of personnel to the new aircraft must be carefully managed to ensure appropriate manning levels for the JSF while maintaining an adequate quantity of experienced personnel in the legacy communities. Maintenance of the legacy communities cannot be an afterthought, because they will continue to meet the majority of exercise requirements and operational deployments over the transition timeline.

This thesis presents the Marine Corps Pilot Conversion Analysis Tool (MCPCAT) which uses an integer linear program to provide T/C boards with a means to evaluate the appropriate number of pilots for accession and conversion to the JSF by military occupational specialty (MOS), years of commissioned service (YCS), and level of experience. The goal is to select the right distribution of officers from legacy communities and new accessions to maintain the traditional hierarchical structure of Marine Corps units. MCPCAT enumerates all career paths within the constraints of billet assignment restrictions, and selects those career paths that best satisfy the requirements as new squadrons activate.

The initial solution shows that the DCA plan meets the total pilot accession and conversion requirement based on current schedules, but does not select sufficient junior-ranking officers to maintain the hierarchical structure desired in the JSF community. Additionally, a significant backlog of training flight-hours is accumulated during the first two years of the conversion. This thesis analyzes four alternate policies to address shortfalls in the original solution, which include reducing flight training time, reallocating aircraft, allowing rank substitution, and increasing new accessions. Results from that analysis show that significantly increasing the number of new accessions and conversions of junior-officers improves the solution most, provides the best pilot to billet matches by rank and YCS, and generates the smallest training flight-hour backlog.

ACKNOWLEDGMENTS

I would like to acknowledge the Operational Analysis Division of Marine Corps Combat Development Command for funding this thesis, and LtCol "Dino" Dehmer and Mr. Snider of Manpower and Support Branch of the office of the Deputy Commandant for Aviation for their time, expertise and patience in defining the scope of the problem and pointing me to the sources of input for the analysis. I would like to acknowledge Maj Wiler of the Officer Assignments Branch of Manpower and Reserve affairs, and Maj Peterson of the Aviation Training Branch of Training and Education Command for their contributions.

I would like to thank Professor Robert Dell, Professor Gerald Brown and Professor Matthew Carlyle for their patience, understanding and willingness to teach. GOD bless you.

My deepest appreciation goes to my wife, Tonya, and our children, Demoriea, Vincent, Savannah, and Dalton for their unending love, support, and understanding.

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I. INTRODUCTION

The USMC is currently planning to transition from F/A-18 A/C/D Hornets and AV-8B Harriers to the new F-35 Joint Strike Fighter (JSF) over the next 16 years. The DCA manages manpower requirements to support new aircraft through boards which select the best qualified applicants for T/C training. These boards serve to balance current pilot inventories with future Marine Corps requirements. In the current case, two aircraft and their associated Military Occupational Specialty (MOS) will become obsolete. The conversion of personnel to the new F-35 must be carefully managed to ensure appropriate manning levels for the JSF while maintaining adequate quantities of experienced personnel in the legacy communities. Maintenance of the legacy communities cannot be an afterthought, because they will continue to meet exercise requirements and operational deployments over the transition timeline. This thesis develops an integer linear program that prescribes a number of pilots in each month for accession and conversion over a 12-year horizon. The number of pilots brought into the new community will be limited by the number of aircraft and flight-hours available for training. The resulting recommendations for selection assist in analyzing current and proposed policies required to develop a balanced, operationally viable community without exceeding standard restrictions on total force end strength.

A. THESIS ORGANIZATION

The remainder of this chapter discusses background and development of the JSF program, legacy aircraft, and the objective of this thesis. Chapter II presents an historical development of manpower planning, its evolution in the military, and other work related to this thesis. Chapter III introduces the MCPCAT and its integer linear program formulation. Chapter IV covers model implementation and results, and Chapter V provides an analysis of results and recommendations for further research.

B. BACKGROUND

The F-35 JSF (see Figure 1) program is the Department of Defense's (DoD) overarching program to replace aging aircraft in the Navy, Marine Corps and Air Force. The purpose is to provide the next generation strike fighter weapons system to meet an advanced threat, while improving lethality, survivability, and supportability. It is both the DoD's largest weapons procurement in terms of total estimated acquisition cost and its largest cooperative development program of record (Gertler, 2009, p. 10).

Figure 1. F-35B takes to the air for the first time on June 11, 2008 (From Lockheed Martin, 2008).

The Marine Corps' version of the JSF, the F-35B Short Take-off Vertical Landing, will replace three existing legacy aircraft in the inventory: the AV-8B Harrier, the F/A-18 A/C/D Hornet and the EA-6B Prowler.

For the United States, the current plan will purchase a total of 2,456 aircraft at an estimated cost of $246 billion in FY2009 dollars (Gertler, 2009, p.1). Internationally, the DoD has memorandums of understanding for strategic development and demonstration with Canada, the United Kingdom, Denmark, the Netherlands, Norway, Italy, Turkey, and Australia, with possible future sales to Israel, Singapore, India, Brazil, Spain, Finland, Japan and South Korea (Gertler, 2009, p.10).

In 1993, the DoD Bottom Up Review (BUR) determined that separate tactical aviation modernization programs for each service were not fiscally sustainable and canceled the Air Forces Multi-Role Fighter and the Navy's Advanced Strike Aircraft programs. Acknowledging that the need for a future capability remained, the BUR initiated the Joint Advanced Strike Technology (JAST) effort to create building blocks for affordable development of the next-generation strike weapons system (Aspin, 1993).

The JSF program resulted from a 1995 review of the JAST effort, and in the same year legislation merged it with the Defense Advanced Research Projects Agency Advanced Short Takeoff and Vertical Landing (STOVL) program. From the beginning, this program was structured to be a model of acquisition reform, with an emphasis on jointness.

The F-35 was conceived as a relatively affordable fifth-generation strike fighter that could be procured in highly common variants, while meeting the similar but unique operational needs of the Navy, Marine Corps, and Air Force. The concept consists of building three highly common variants on the same production line using flexible manufacturing technology, where cost benefits result from flexible manufacturing and common subsystems. As stated by the Federation of American Scientists, "JSF will benefit from many of the same technologies developed for F-22 and will capitalize on commonality and modularity to maximize affordability."

In the JSF Operational Requirements Document, the Marine Corps summarizes its mission need for a stealthy, multi-role, STOVL strike fighter to replace the aging AV-8B and F/A-18 A/C/D aircraft. As one component in the aviation element of the Marine Air-Ground Task Force (MAGTF), it must be capable of expeditionary basing ashore and/or deployment at sea. The forward-deployed and expeditionary nature of the MAGTF require that its tactical aviation assets be capable of independent, decisive action across a range of assigned missions within all six functions of Marine aviation: offensive air support, anti-air warfare, aerial reconnaissance, electronic warfare, escort of assault support, and control of aircraft and missiles. The F-35B must be capable of operating from Amphibious Assault Ships, and aircraft carriers within the projected command, control, communications, computers, intelligence, and reconnaissance architecture.

Key performance parameters required by the Marine Corps include a minimum combat radius or 450 nautical miles with a goal of 550 nautical miles, mission reliability of 95% with a goal of 98%, and a logistics footprint of less than 21,000 cubic feet and 136 short tons, with a goal of 15,000 cubic feet and 104 short tons. Additional key performance parameter and performance characteristics can be reviewed in the JSF Operational Requirements Document (2000).

C. LEGACY AIRCRAFT

The F/A-18 was originally envisioned as two separate aircrafts; one fighter and one attack, which would replace the Navy and Marine Corps' existing fleet of F-4s and A-7s.

Figure 2. F/A-18 Carrier Landing (From 1000pictures.com).

The F/A-18 entered service in the Marine Corps in 1983. The Marine Corps currently has three versions of the F/A-18 in its inventory, single-seat versions A and C, and the two-seat version D.

The F-18 would be an escort fighter that would defend the Navy fleet while its twin, the A-18, would perform ground attack missions. The original contract awarded to McDonnell Douglas in May of 1975 called for a single-seat, twin-jet fighter, and an attack aircraft that could operate from carriers or a land base.

The two aircraft were designed with 99% commonality, and after the three-year test program, it was proven that one design could perform both missions. The aircraft was re-designated the F/A-18 in 1982, and officially entered operational service with the Marine Corps in January 1983.

The Marine Corps currently has three versions of the F/A-18 in its inventory; single-seat versions A and C, and the two-seat version D. There are three active duty F/A-18A squadrons, five F/A-18C squadrons and five F/A-18D squadrons, each with 12 planes.

The AV-8B Harrier is a single-seat, light attack aircraft that provides offensive air support to the MAGTF. By virtue of its STOVL capability, the AV-8B can operate from a variety of amphibious ships, rapidly constructed expeditionary airfields, forward sites (e.g., roads), and damaged conventional airfields. This makes the aircraft particularly well suited for providing dedicated close air support.

The AV-8B's history dates back a bit further than the F/A-18 with the Marine Corps requirement for a STOVL light attack force being identified in the late 1950s. The STOVL aircraft originated with a French engine concept introduced in 1957, later funded by the British Bristol Engine Company and the U. S. Government through a mutual Weapons Development Program. In 1966 the U.S. received six XV-6A aircraft for testing and during the early 1970s initiated procurement of the AV-8A. In 1973, Hawker-Siddley and McDonnell Douglass initiated a joint advanced program to improve the Harrier, but increased costs for airframe and engine development led to abandonment of the project.

Going at it alone, McDonnell revised the configuration, incorporating a composite wing that promised most of the previous design capabilities without changing the engine. Full testing led to the AV-8B whose first squadron fully stood up in 1985. The Marine Corps currently has 7 active duty harrier squadrons with 12 aircraft each.

Figure 3. AV-8B Carrier Operations (From Aviationspectator.com).
The AV-8B Harrier is a single-seat, light attack aircraft that provides offensive air support to the MAGTF.

D. THESIS OBJECTIVE

This thesis introduces the Marine Corps Pilot Conversion Analysis Tool (MCPCAT), a decision support tool that uses an integer linear program to prescribe the number of pilots for conversion and accession into the JSF community, each month, over a 16-year planning horizon, based on the aircraft delivery schedule and squadron activations and deactivations. Career paths are generated by enumerating all possible career cycles (tours of duty) that are available to a pilot. By prescribing a path for each pilot we determine the number of pilots for conversion and accession each month, based on rank, years of commissioned service (YCS), and whether or not the pilot has F-35 experience. The requirement for pilots in each squadron is identified in the table of organization (T/O) which specifies the manning requirements for the unit. The number of pilots that can be brought into the new community is limited by the number of aircraft and flight-hours available for training. MCPCAT will assist T/C boards in selecting pilots that will meet billet requirements while maintaining the traditional command structure of Marine Corps units.

Command (hierarchical) structure refers to the pyramid-shaped organization of manpower in the Marine Corps; the number of officers assigned to a unit decreases as the rank increases. This facilitates the chain of command. In the instance of a ten plane JSF squadron, the unit table of organization authorizes 22 pilots: one Lieutenant Colonel, four Majors, six Captains, and six First Lieutenants.

Selection based on the best qualified individuals can have unintended consequences on the hierarchical structure of an organization. Traditionally, the number of conversions to a new MOS is small, and a few additional higher ranking officers have minimal effect on the community as a whole. For the JSF, two communities of pilots will convert to a new MOS. Using the existing criteria, those best suited for conversion will tend to be higher-ranking officers who have more experience and more years of commissioned service. Selection based on the current criteria could easily skew the existing hierarchical structure by adding too many higher-ranking officers. An objective of this work is to evaluate T/C selection policies in order to maintain the normal pyramid-shaped structure throughout the transition horizon.

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II. MANPOWER PLANNING

Manpower planning involves reviewing current manpower resources, forecasting future requirements, and taking steps to ensure a supply of people with appropriate skills is available to meet demand. The Commandant of the Marine Corps, in concurrence with literature, defines manpower planning as assigning the right people to the right place at the right time. Grinold and Marshall (1977) observe that frequently restrictions of the governing system prevent perfect matching of people to jobs, and suggest that a more realistic definition of manpower planning may be that it avoids having too many of the wrong types of people in the wrong jobs too frequently.

A. HISTORY AND DEVELOPMENT OF MANPOWER PLANNING

> ...although a strict definition may elude us, it is nevertheless possible to point to the essential matter with which it is concerned, that is with the matching of manpower requirements and resources. (Bartholomew & Morris, 1971)

Manpower planning, as an area of study and analysis, can be traced to the Second World War (Charnes et al., 1972) and although *manpower planning* may be a relatively new term (dating to 1960), concern over these types of issues dates back many centuries. With the advent of the computer, the 1950s and 1960s saw a growing interest in manpower planning. As interest shifted from using manpower planning for trend analysis, to decision support for policy making, this area of study attracted much attention and saw explosive growth between 1965 and 1970.

The primary function of manpower planning is to analyze and evaluate human resources available in an organization and to determine how to recruit personnel needed to staff job requirements. Manpower planning aims to reduce waste in employing people, lessen uncertainty in manning levels and future requirements, and eliminate mistakes in assigning people to jobs. This type of analysis provides decision makers with the information needed to evaluate and implement policies that will shape the workforce to meet the organizations requirements, recruit and/or maintain desired skills, and eliminate costly waste of labor overages or shortages.

Dill, Gaver, and Weber (1966) discuss the growing attention to long-range planning required in the management of large organizations and explore issues in manpower planning. They look specifically into stochastic models and simulation as two approaches that show promise for this type of analysis.

Charnes et al., (1972), provide a collection of reports on models and studies on manpower management and planning done for the U.S. Navy’s Office of Civilian Manpower Management. Included are a summary of modeling efforts and the mathematics behind them, models for aggregate manpower planning and assignment problems.

Bryant, Maggard and Taylor (1973) review the increasing need for manpower planning based on the tightening supply of high-talent manpower and people with technical knowledge, along with the increasing cost of human resources. They describe four main techniques for manpower modeling as: (1) using opinion or informed judgement; (2) matrix models; (3) quantitative techniques; and (4) computer simulation models.

Smith and Bartholomew (1988) outline the recorded development of manpower planning in the U.K., and reference its origin as work done by Seal and Vajda for the Admiralty of the Royal Navy. They also mention work by one of the first actuaries, John Rowe, who as early as 1779, conducted studies on the career structures, wastage rates, and promotion prospects in the Royal Marines.

B. EARLY MANPOWER PLANNING EFFORTS IN THE U.S. MILITARY

> The idea of using mathematical and statistical techniques to obtain better information on the manpower requirements has its roots in personnel research started by the Armed Services during World War II. (Charnes et al., 1972)

During the 1960s, the Office of the Deputy Chief of Staff for Personnel was charged with providing monthly forecasts of Army strength and projected accessions for both draftees and volunteers, along with target strengths and projected overages or shortages. The information was presented to the Assistant Secretary of the Army

(Manpower and Reserve Affairs) using a replacement chart, which he found to be useful in conducting what-if analysis (Holz & Worth, 1980).

Defining replacement charts, Bryant et al. (1973) write:

> A replacement chart is a graphic device designed to insure that suitable replacements are ready to move into vacated positions as vacancies occur among incumbent personnel. The device may make use of such data as the incumbent's age, performance level, promotability, and the name and degree of readiness of the incumbent's "backup" man. More sophisticated charts may make use of much more data, such as age, internal historical information actuarial statistics, and estimates or opinions about where and when vacancies may occur. This technique's chief disadvantage is that constructing such a chart may require a great deal of labor in the assembly and compilation of the data.

Though the military was engaged in manpower analysis, there is a definite increase in the number of publications addressing the application of mathematical modeling to military manpower issues during the late 1960s and early 1970s. Two specific issues can be associated with the increasing requirement for long-term planning: (1) with the end of the Vietnam War congress was mandating reductions in the total end strength of the armed services, which would require drastic policy changes in order to draw down the force; and (2) the draft was ending, and the DoD would transition to an all-volunteer force that would require policy changes to military compensation, and would allow it to compete with the civilian sector for manpower.

Literature from this period includes Daniels (1967), who develops a network flow model to represent the U.S. Navy officer personnel system. He evaluates a measure to relate planning effectiveness to the dollar costs incurred by the Navy in recruiting, training and maintaining officers. The model determines the number of officers necessary to meet expected future requirements with maximum planning effectiveness; hypothesized data is used to illustrate the technique.

Fields (1967) discusses how the cross-fertilization of ideas for resolving assignment problems in the Army, the Navy, and the Marine Corps, leads to the development and testing of Computer Assisted Assignment of Recruits for use at the U.S. Naval training center, San Diego, in November 1965.

Other publications that address DoD concerns during this period include: Fisher and Morton (1967), who analyze incentive policies to increase the first-term reenlistment rate in the Navy; Fisher (1969), who studies the cost of the draft versus the cost of not having a draft; Charnes et al. (1972), whose work is detailed in the previous section; Altman and Fechter (1967), who study army enlistments and the all volunteer force; and Jaquette and Nelson (1976), who address the policy issues related to compensation of an all volunteer military force using a goal programming model.

Holz and Worth (1980) chronicle the progression of Army manpower planning models from the replacement chart to their first optimization model, Computation of Manpower Programs Using Linear Programming, and the Enlisted Loss Inventory Model, used to project losses due to congressionally-mandated reductions of Army end strength following the Vietnam War.

C. RECENT WORK RELATED TO THIS THESIS

Baumgarten (2000) presents an integer linear program with set covering constraints that prescribes the optimal set of career paths for a cohort of Marine Corps officers with the infantry MOS. He implements a JAVA program called Career Path Generator (CPG) to create a set of valid career paths for each member of the cohort. A path is valid if each assignment in the path meets a billet requirement, meets tour length constraints, and develops a core competency of the officer. From billet and assignment inputs, CPG generates over 18,000 suitable career paths which receive a "competency value" based the level at which they meet all constraints. The objective of the model is to minimize penalties associated with underfilling or overfilling the requirement for billet assignments.

Jasperson (1999) develops an optimization model to assist the Navy helicopter training squadron determine the rate and method with which training should be conducted during the transition to new helicopters over a seven-year planning horizon. Jasperson generates career cycles based on four dimensions of aircrew qualification, billet assignment and the job during that assignment. The model forecasts personnel requirements and recommends an optimal mix of pilots, air crewmen and class size to start training each month. Prior to his work, the training schedule was developed manually and maintained in an excel spreadsheet. Jasperson's work validated the manually developed schedule and identified possible shortages in instructor pilots during the first year of transition.

This thesis prescribes the number of pilots available for accession or conversion to fill squadron demand, for each month of the 16-year horizon. While Baumgarten optimizes the selection of a set of career paths for one cohort of officers at a specific time, Jasperson solves for a feasible monthly training schedule that optimizes the training squadrons resources.

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III PROBLEM DEFINITION AND FORMULATION

The transition to the Joint Strike Fighter presents a problem of prescribing the right types of pilots for accession and conversion to F-35 squadrons as they activate over the next 12 years. In our formulation, career paths are generated by enumerating all possible career cycles (tours of duty) that are available to a pilot. The integer linear program prescribes the number of pilots for conversion and accession into the JSF community, for each month, over a 12-year planning horizon by selecting the career paths that best satisfy the billet requirements by rank, experience, and YCS. The number of pilots that can enter the new community is limited by aircraft and flight-hours available for training. The objective is to minimize the summation of elastic penalties that are associated with manning shortages and overages, while filling all billet demands.

A. USMC JOINT STRIKE FIGHTER TRANSITION PLAN

The current Marine Corps transition plan is based on a fixed aircraft delivery schedule and extends from FY2010 through FY2026. Two deactivated squadrons will be re-activated, and then re-designated as the first two operational JSF squadrons, while 7 AV-8B squadrons and 13 F/A-18 squadrons will transition to the new JSF over the prescribed timeline. At completion of the transition, the Marine Corps will have seven F-35 squadrons with 16 aircraft and 14 squadrons with 10 aircraft, for a total of 21 operational F-35 squadrons. There will also be three Fleet Replacement Squadrons with 20 aircraft each.

The initial Fleet Replacement Squadron (FRS), VMFAT 501, stood up on 2 April 2010 at Eglin Air Force Base, Florida. VMFAT 501 will provide the initial entry-level training and readiness syllabus instruction for pilots assigned to the JSF. Advanced training and readiness instruction will be conducted at the operational squadrons. Two additional FRSs, VMFAT 502 and VMFAT 503, will be established in Beaufort, South Carolina, and will activate in 2014 and 2017 respectively.

Three of five test aircraft have already been delivered to Marine Corps Air Station Patuxent River for operational test and evaluation. These aircraft will be used to evaluate the vehicle systems and also focus on weapons testing. The last two aircraft will be used to test the aircraft's integrated mission systems.

VMFAT 501 expects its first aircraft during December 2010, with another nine aircraft being delivered in 2011. It will receive another three aircraft in 2012, but will also transfer three aircraft to operational test and evaluation. VMFAT 501 will receive its final compliment of aircraft in 2013, rounding out the 20 required for the initial FRS.

B. DEMAND FOR PILOTS

The demand for pilots in a specific period is driven by the schedule to activate new JSF squadrons. Based on the current aircraft delivery schedule the DCA has planned the activation and transition of all USMC JSF squadrons through 2026. Pilots will have to be trained in the JSF prior to a new squadron operating. The requirement for pilots in each squadron is identified in T/O with each billet designated by a billet identification code that specifies the job title, grade, rank and MOS requirements, along with any special qualifications required for the position.

The flow of events that occurs for the activation of a squadron will follow the same basic pattern:

- Ready for operation (RFO) occurs with the initial assignment of personnel and support equipment to the unit and occurs six months prior to delivery of the first plane. The unit activation usually occurs two months prior to the delivery of the first aircraft.
- First Aircraft Arrival (FAA) is the date that the first aircraft is delivered to the unit. Prior to this date, the unit will be activated and is required to have at least eight pilots who have completed advanced training, and have the maintenance and support personnel to conduct operations. FAA should occur no later than six months after RFO.
- Initial Operational Capability (IOC) identifies that a unit has 90% of its personnel, at least 10 aircraft, all of the necessary support equipment, and can execute the daily flight schedule for training and readiness syllabus events in support of unit mission tasks. IOC should occur no later than eight months after FAA.

- Full Operational Capability (FOC) occurs when a unit has received 95% of its personnel, all planes and support equipment and is autonomously capable of executing daily flight schedule and meets requirements to conduct identified essential tasks in accordance with the applicable training and readiness manual.

C. SUPPLY OF PILOTS

1. Experienced Pilots

Pilots available for conversion to the JSF are determined by squadron deactivations and transitions. Pilots available for conversion consist of the existing inventory of F/A-18 and AV-8B pilots who are in a squadron that is standing down, who meet the criteria for conversion, and are available for reassignment.

The daily inventory of pilots can be easily queried from the Marine Corps Total Force Structure (MCTFS) database or the Operational Data Store Enterprise, which records a snapshot of MCTFS during each daily update.

2. New Accessions

New accessions are pilots who have completed jet training and are available for assignment to the JSF. According to the Aviation Training Branch at Training and Education Command, the Marine Corps contracts an average of 400 new pilots each year, of which approximately five percent make it into the jet pipeline.

D. NAVAL AVIATOR TRAINING (NEW ACCESSIONS)

For all Naval Aviators, flight training begins at Naval Air Station (NAS) Pensacola, Florida. Initial flight screening takes about 60 days and is not required for entries that already possess a civilian license. Following are six weeks of aviation preflight indoctrination (API) which consists of 177 hours of basic academic fight instruction and survival training. After indoctrination, students are designated student naval aviators and proceed to primary training which lasts between 20 and 30 weeks, averaging 24 weeks at NAS Whiting Field, Milton, Florida, NAS Corpus Christi, Texas, or Vance Air Force Base, Enid, Oklahoma. Near the end of primary flight training, students are selected to specialize in one type of aircraft: jets, helicopters, tilt rotors or turboprops based on current and projected needs of the services and the student's performance and preferences.

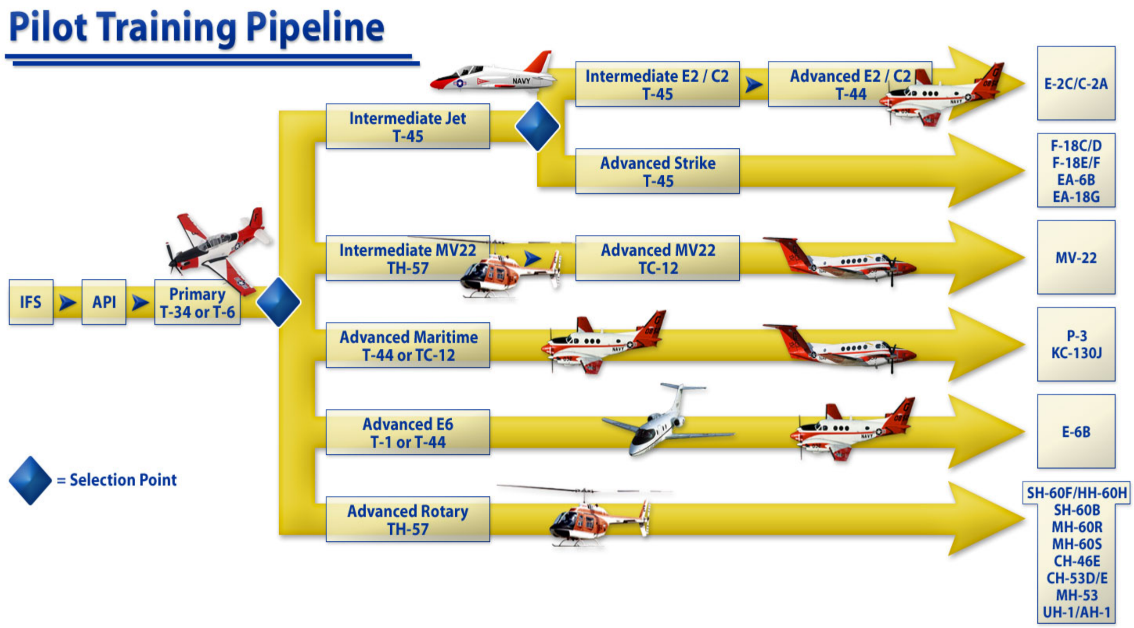

Figure 4. Aviator training pipeline (From Chief of Naval Air Training, 2010)

Advanced flight training for the jet pipeline is conducted at NAS Kingsville, Texas, or NAS Meridian MS and last from 45–55 weeks depending upon the aircraft. After completing Advanced Flight Training, pilots earn their wings, are designated Naval Aviators and report to their designated FRS for type, model, and series specific training.

NAS Pensacola conducts 48 API classes per year with a course commencing almost every week except during holidays. Courses last exactly 6 ½ weeks. The three NAS's previously listed for primary training also conduct 48 classes per year with a class commencing almost every week. Course starts require three or four aviators.

E. TRANSITION TRAINING REQUIREMENTS

VMFAT 501 will be the sole source for training JSF pilots in the Marines Corps for at least the first two years. In order to be able to immediately integrate and employ the new platform, the required personnel will have to be trained and in place prior to delivery of the aircraft to the squadron. A transition task force has been organized to identify requirements and develop solutions in order to meet the desired end state. All pilot entries into the community (throughput), will be limited by the number that can be trained at the FRS.

Training requirements have been separated into six levels of qualifications for JSF pilots, levels 1000 thru 6000. Only 1000 level training will be conducted at the FRS. Successively more advanced levels 2000, 3000, and 4000 will be conducted at the individual squadrons. Level 5000 consist of instructor-level qualifications while level 6000 consist of special weapons qualifications.

The experience level of the pilot refers strictly to JSF experience. All pilots entering the community will be inexperienced (new) in the beginning. For the purposes of this thesis, we assume a pilot has become experienced after two years of flying the JSF.

Category		Training Time Required
Category 1	IQ – Initial Qualification	9 months
Category 2	TX - Transition	6 months
Category 3	RQ – Requalification >2 years	3 months
Category 4	RQ – Requalification < 2 years	1 month
Category 5	RQ – Requalification <1 year	2 weeks

Table 1. Training requirements based on pilot experience.

Training requirements for pilots are determined by their previous qualifications, flying experience, and amount of time in non-flying billets. This table lists the training time requirements for pilots based on their assigned category.

For training purposes, pilots are separated into different categories based on previous qualifications, flying experience, and duration of time in non-flying billets. “Category 1” pilots consist of those requiring initial qualification on an aircraft, usually first lieutenants or captains coming out of intermediate flight training. “Category 2” pilots are transitioning from an existing platform in the Marine Corps inventory. “Category 3” pilots are experienced, but have not flown in more than two years, and require requalification. “Category 4” and “Category 5” pilots are experienced, but have been out of the cockpit for less than two years. Their re-qualifications are handled by the individual operational squadrons and have no effect on the FRS schedule. Table 1 outlines the training time required for each pilot category.

F. USMC OFFICER ASSIGNMENT

The Officers Assignment Branch of Manpower and Reserve Affairs (MMOA) executes Marine Corps policy to assign all active duty officers to authorized billets to maintain the operational readiness of the Marine Corps. The general policy of the Marine Corps is to minimize permanent change of station (PCS) moves while ensuring combat readiness, equitable treatment and career development of each individual Marine officer (MCO P1300.8R, 1994). The mission of the assignment branch, as stated in the 2010 Road Show power point presentation is “to put the right officer in the right billet at the right time for the right reason.”

Each assignment strives to provide the Marine with an opportunity to gain experience in his core competency, develop individual and professional skills and/or expand his general knowledge of the Marine Corps. This is accomplished by alternating assignments between the operating forces and supporting establishment or school assignments in an effort to professionally develop officers for billets requiring greater authority and responsibility. According to Marine Corps Order (MCO) 1300.8R, Personnel Assignment Policy, monitors make assignments based on the following priorities (listed in order of precedence):

- Needs of the Marine Corps
- MOS and billet variety – command versus staff tour
- Availability of the individual
- Overseas Control Date
- Seniority
- Individual preference

Under normal circumstances, MMOA assigns orders based on a summer rotation cycle (June, July, and August) with most report dates to the gaining command as 31 July.

In accordance with MCO, the minimum tour length for PCS orders is 36 months with the exception of schools (Expeditionary Warfare School (EWS), Command and Staff College (CSC)) executed en-route to a new duty station.

G. CAREER CYCLE ENUMERATION

A career path is the history of school and job assignments that a Marine accumulates during his service in the Corps. Paths are not specifically assigned, but are developed over many years as a Marine rotates between units and duty stations**.**

For this thesis, a career cycle is designated as a single assignment to a specific billet for a specific duration. Table 5 outlines the length of career cycle choices which are designated as flying and non-flying billets. The career cycles were developed from Marine Corps assignment policy and discussions with the Officer Assignments branch of Manpower and Reserve Affairs, and provide the most common tour lengths of probable assignments that a pilot might encounter over a career.

The total career of any individual pilot consists of a succession of career cycles and is designated as a career path. A career path here consists of the concatenation of career cycles over a 12-year planning horizon. No two career paths are the same, even if two Marines follow the same assignments; any difference in the duration of a single assignment would result in a different career path. This is not all inclusive, but in enumerating all possible combinations, we can reasonably replicate the current pilot population.

	FRS	1st Tour	2nd Tour	3rd Tour	4th Tour	5th Tour	6th Tour	7th Tour
Career Paths	9-12 mo	36 mo	12(EWS)	36 mo	12 (CSC)	36 mo	36 mo	36 mo
Flying			18 mo	24 mo	24 mo	36 mo	36 mo	36 mo
Not Flying			24 mo	36 mo	36 mo	24 mo	24 mo	24 mo
			36 mo	24 mo	36 mo			
			36 mo		24 mo			
			24 mo					
		1st Tour	2nd Tour	3rd Tour	4th Tour	5th Tour	6th Tour	
Examples		36 mo	12 (EWS)	36 mo	12(CSC)	36 mo	36 mo	
		36 mo	18 mo	24 mo	36 mo	36 mo	36 mo	
		36 mo	24 mo	36 mo	36 mo	36 mo	36 mo	
		36 mo	36 mo	36 mo	12(CSC)	36 mo	36 mo	
		36 mo	36 mo	24	36 mo	36 mo	36 mo	
		36 mo	36 mo	36	36 mo	36 mo	36 mo	

Table 2. Career cycles.

This table displays possible career cycle choices based on assignment duration in flying and non-flying billets. Career paths are generated by concatenating career cycle choices for each tour over the duration of the planning horizon. In the first example career path, a pilot has completed entry level training at the FRS and is assigned to a flying billet for 36 months. He is subsequently assigned to EWS for 12 months where he is not flying, a flying billet for 36 months, CSC for 12 months where he is not flying, a flying billet for 36 months, and a non-flying billet (staff) for 36 months.

For this thesis, the career path is mathematically represented as a column vector of binary digits that represent each assignment. The vector of 144 digits represents the monthly periods over 12 years. “0” indicates the pilot is assigned to a ground billet, and “1” indicates the pilot is assigned to a flying billet.

The first example in Table 2 is a career path where the pilot completes training at the FRS and is then assigned a sequence of billets: a 36-month flying billet, a 12-month school, a 36-month flying billet, a 12 month school, a 36-month flying billet, and then a 36-month ground billet. The vector representation would consist of 36 “1s” followed by 12 “0s,” then 36 “1s,” and so on. Figure 5 shows some examples of the row vector representation of five career paths over one year.

	tDEC10	tJAN11	tFEB11	tMAR11	tAPR11	tMAY11	tJUN11	tJUL11	tAUG11	tSEP11	tOCT11	tNOV11	tDEC11
c1	1	1	1	1	1	1	1	1	1	1	1	1	1
c2	0	0	0	0	0	0	1	1	1	1	1	1	1
c3	0	0	0	0	0	0	0	0	0	0	0	0	1
c4	0	0	0	0	0	0	0	0	0	0	0	0	0
c5	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3. Career path examples.

Examples of 5 career paths assigned to flying and non-flying billets annotated by binary digits, 1 and 0, respectively, over one year. Row C1 is assigned to a flying billet for each of 12 months from December 2010 thru December 2011. Row C2 is only assigned to a flying billet for 7 months, and row C3 for 1 month. C4 & C5 are assigned to ground billets during the entire period, shown.

Total enumeration of career paths over each month of the 12-year planning horizon yields an upper bound of over 32 trillion paths. This is calculated by multiplying the number of choices in each tour by the number of months a tour could start (12 months each year), and the number of different groups of Marines by YCS that could start each path. For example, the first tour has one option, the second tour has six, the third has four, etc,. Each of these paths could start in each month of the 12-year planning horizon, for any Marine between three and 26 YCS.

$$(1)(6)(4)(5)(3)(3)(3)(12^7)(12)(23) = \quad 32,042,235,985,920$$

Assignment guidelines are utilized to constrain the generation of career paths to those that could be accomplished under normal Marine Corps assignments. We reduce the number of paths generated by excluding paths that violate assignment guidelines, limiting assignment months to June, and eliminating Marines with higher YCS from starting career paths toward the end of the planning horizon. These constraints reduce the upper bound on the number of paths to just over 583 thousand.

$$(1)(6)(4)(5)(3)(3)(3)(1 month)(12 yrs)(15 YCS) = 583,200$$

H. MANPOWER FLOW

As with most organizations, manpower in the Marine Corps evolves over time. New Marines join, get promoted, separate voluntarily or not, or stay through retirement. We use a probabilistic Markov chain (cross-sectional model) to describe the behavior of pilots as they age through the system. Continuation rates that characterize the probability of a person in the system in one period, being in the system at some future period, are generated from historical attrition and promotion data for Captains, Majors, and Lieutenant Colonels, and are provided for our use by MMOA.

I. ELASTIC PROGRAMMING

Because of limited assets, it is not always possible to satisfy all constraints of our problem. We allow necessary violations of constraints at a cost. The constraint ranges become goals that incur a linear penalty per unit violation (Brown, et al., 1997).

J. CURRENT METHOD OF SELECTION FOR CONVERSION

MCO 1331.2k governs the existing process for transitioning naval aviators to a new aircraft via a T/C board. The purpose of the T/C board is to balance aviator inventories with Marine Corps requirements. Typically, naval aviators transition from one type, model, series, aircraft to another in order to broaden their aviation MOS. When an aircraft, and thus MOS, becomes obsolete, the needs of the Marine Corps require an entire MOS community to transition or convert (MCO 1331.2K, 2003).

In accordance with MCO 1331.2k, when a naval aviators MOS becomes obsolete, “naval aviators with more than 13 YCS will not be considered for T/C training unless they are both selected for Lieutenant Colonel and selected for command of an aviation squadron.” Those with limited selection opportunity may either retain the MOS and pursue career opportunities through aviation staff, or lateral move to ground MOS fields.

Traditionally, request for T/C are from one existing aircraft to another and the number of applicants is a small percentage of the population. There is no mandatory percentage of selection or quota, boards are only required to select those officers determined to be most qualified by a majority of the board.

K. MODEL PRESCRIPTIONS

The solution of this model prescribes with monthly fidelity:

- The number of transitioning Marines by MOS and rank to start training.
- The number of accessed Marines by MOS and rank to start training.

- Any shortages to desired manning levels.
- The utilization of training flight-hours.

L. FORMULATION

Sets

t, ta	time periods (months) [~140]
f	fiscal years [~12]
r	rank [4]
y	years of commissioned service (YCS) [~20]
$ry(r,y)$	rank r associated with YCS y
e	experience level {new, exp} [2]
p	types of already transitioned pilots [~20]
c	career path (columns) [~100000]
$cp(c,p)$	career path c appropriate for already transitioned pilots of type p
$ct(c,t)$	career path c starts in time period t
$cy(c,y)$	career path c begins with y years of commissioned service
$cety(c,e,t,y)$	career path c has experience e in period t and starts with y YCS

Data

$req_{r,e,t}$	requirement for pilots of rank r, experience e, in period t
$nt_{t,y}$	number of pilots available to transition in period t with y YCS
nn_t	number of new pilots available in period t
$ret_{c,t}$	proportion of pilots starting on career path c still available (retained) in period t
fh_t	training flight-hours available in period t
$fhours_{c,t}$	training flight-hours for path c required in period t
$pinit_p$	initial number of pilots of type p already transitioned
$retain_y$	fraction of pilots that reach y YCS

maxwait maximum number of years pilots remain in pool of available transitions

Calculated Data

$s_{c,e,ta,r}$ fraction of pilots starting career path c with rank r, experience e that are in flying billets in period ta

Variables

X_c number of pilots starting career path c [integer]

$SUB_{r,e,t}$ number of pilots of rank r, experience e used to fill billets for rank r+1 in period t

EFH_{ta} backlog of flight hours in period ta

Formulation

Minimize *elastic penalties* (0)

Subject to:

$$\sum_{\substack{e'\geq e \\ y:ry(r,y) \\ c:cety(c,e',t,y)}} s_{c,e',t,y} X_c + \sum_{e'\geq e}\left(SUB_{r-1,e',t} - SUB_{r,e',t}\right) \overset{\circ}{=} \sum_{e'\geq e} req_{r,e',t}$$

$$\forall e \in E, r \in R, t \in T \quad (1)$$

$$\sum_{\substack{t-maxwait<t'\leq t \\ c:ct(c,t')\wedge cy(c,y)}} X_c \leq \begin{cases} nt_{t,y} & y>1 \\ nn_t + nt_{t,y} & y=1 \end{cases} \qquad \forall t \in T, y \in Y \quad (2)$$

$$\sum_{e'\geq e} SUB_{r,e',t} \leq \sum_{\substack{(c,e',y):cety(c,e',t,y) \\ \wedge yr(y,r)\wedge e'\geq e}} s_{c,e',t,y} X_c \qquad \forall e \in E, r \in R, t \in T \quad (3)$$

$$\sum_{c\in C} fhours_{c,ta} X_c + EFH_{ta-1} \leq fh_{ta} + EFH_{ta} \qquad \forall ta \in T \quad (4)$$

$$\sum_{c:cp(c,p)} X_c = pinit_p \qquad \forall p \in P \quad (5)$$

$$X_c \in Z^+ \qquad \forall c \in C, t \in T \tag{6}$$

The objective is to minimize the sum of weighted deficiency variables associated with shortages and excesses of pilots by rank *r*, experience level *e*, in each month of the planning horizon. The first constraint (1) computes the number of pilots above or below the number required by new squadrons for each month of the planning horizon. Deficiency variables associated with each rank *r* allow for deviation from the specified requirement of experience level *e*, in each month *t*, of the planning horizon. Brown et al. (1997) describe the use of elastic notation used in this constraint.

The first term sums the number of pilots with career path *c*, experience *e*, years of commissioned service *y*, and rank *r*, starting in month *t*, that are assignable in month $ta \geq t$. The second term facilitates rank substitution by allowing officers of to fill billets of the next higher rank, e.g. Captains filling billets requiring a Major. Constraints (2) limit the number of pilots prescribed for conversion to the number available for conversion each period, by YCS, and the number available for conversion plus the number of new pilots available for assignment each period. Constraints (3) limit the number of substitutions of lower-rank officers for higher-rank jobs to the number of officers available at the lower rank in any time period. Constraint (4) requires that the number of flight-hours used for training a pilot with career path *c*, starting in month *t*, for assignment in month *ta*, is less than or equal to the number of flight-hours available for training in each month of the planning horizon. Constraint (5) requires that the number of pilots prescribed for transition in the first month of the planning horizon be equal to the number of pilots who have already transitioned to the JSF. (6) stipulates that career starts are non-negative integer (whole) numbers.

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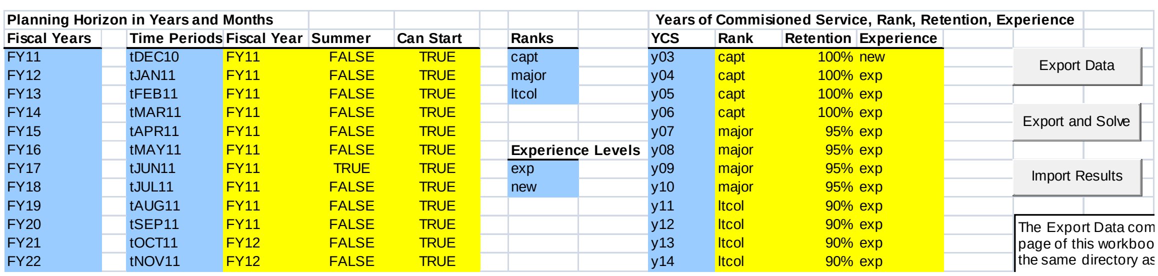
IV. IMPLEMENTATION, RESULTS, AND ANALYSIS

A. IMPLEMENTATION

1. Graphical User Interface

The model is hosted in Microsoft Excel (2007) and both the planner inputs and solutions are maintained in one workbook. A macro is used to export data to General Algebraic Modeling System (GAMS) for solution with CPLEX version 11.2.0 (GAMS 2010), which is returned in the last six tabs of the workbook. The first four tabs of the workbook contain static data that should not require planner update. This data can be changed to evaluate delays in the delivery schedule, changes to pilot assignment policy, or different continuation rates. Figure 5 displays a snapshot of the first tab in the workbook, "Control." The control tab contains the sets of values that variables in the formulation are allowed to assume. The fiscal years (FY) of the planning horizon are listed in the first column, followed by the months of the calendar year (CY) which are the planning periods.



Planning Horizon in Years and Months				
Fiscal Years	Time Periods	Fiscal Year	Summer	Can Start
FY11	tDEC10	FY11	FALSE	TRUE
FY12	tJAN11	FY11	FALSE	TRUE
FY13	tFEB11	FY11	FALSE	TRUE
FY14	tMAR11	FY11	FALSE	TRUE
FY15	tAPR11	FY11	FALSE	TRUE
FY16	tMAY11	FY11	FALSE	TRUE
FY17	tJUN11	FY11	TRUE	TRUE
FY18	tJUL11	FY11	FALSE	TRUE
FY19	tAUG11	FY11	FALSE	TRUE
FY20	tSEP11	FY11	FALSE	TRUE
FY21	tOCT11	FY12	FALSE	TRUE
FY22	tNOV11	FY12	FALSE	TRUE

Ranks
capt
major
ltcol

Experience Levels
exp
new

Years of Commisioned Service, Rank, Retention, Experience			
YCS	Rank	Retention	Experience
y03	capt	100%	new
y04	capt	100%	exp
y05	capt	100%	exp
y06	capt	100%	exp
y07	major	95%	exp
y08	major	95%	exp
y09	major	95%	exp
y10	major	95%	exp
y11	ltcol	90%	exp
y12	ltcol	90%	exp
y13	ltcol	90%	exp
y14	ltcol	90%	exp

Figure 5. Graphical Interface for Planners.

Example of the Graphical Interface hosted in Microsoft Excel 2007. The control page outlines the sets of values that decision variables are allowed to assume. The "Fiscal Years" and "Time Period" columns define the planning horizon, while the "summer" column defines allowable assignment periods. "YCS," "Rank," and "experience" are characteristics associated with each pilot, and the "Retention" column defines the rates of continuation associated with each rank and YCS.

The "Summer" column defines whether a pilot can be assigned during a given month (here, only June). "Ranks" describe the military ranks of the officers that can be considered for accession or conversion and "Experience Levels" defines whether the pilot is "new" or "exp" with two or more years flying the JSF. "YCS" associates the number of years of commissioned service with each rank. “Retention” provides continuation rates (i.e., the proportion of pilots that will remain at this level) for each rank and YCS.

The second tab, “tours,” is displayed in Table 4 and lists the possible career cycle choices and whether each assignment is a flying tour or not.

Tours								
Length								
		Tour1	**Tour2**	**Tour3**	**Tour4**	**Tour5**	**Tour6**	**Tour7**
		36	36	36	36	36	36	36
			24	36	24	36	36	36
			18	24	12			
			12		36			
			36					
Flying								
		Tour1	**Tour2**	**Tour3**	**Tour4**	**Tour5**	**Tour6**	**Tour7**
		TRUE	FALSE	TRUE	FALSE	TRUE	FALSE	TRUE
			FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
			FALSE	FALSE	FALSE			
			FALSE		TRUE			
			TRUE					

Table 4. Career cycle options.

This table displays the lengths of each career cycle option for a tour. True and False flags are used to identify whether the assignment is a flying billet or not. Career paths are generated by selecting one length in each tour for each designated period for each rank and YCS.

The third tab, “init_trans,” provides data to set the starting conditions for the model. This data represents the number of pilots, by YCS, that have already converted into the JSF community, and the hours and months still required to train them. Table 5 displays information contained in the “init_trans” tab. The model will track remaining pilot time in their current tour and assign a career path for future assignments.

Transitioned Pilots				
YCS	Transitioned	Periods Before Start	Train Hours Required	Train Periods Required
y03	0	0	217	9
y04	0	0	154	6
y05	0	0	154	6
y06	0	0	154	6
y07	0	0	154	6
y08	0	0	154	6
y09	1	0	154	6
y10	0	0	154	6
y11	0	0	154	6
y12	1	0	154	6
y13	1	0	154	6
y14	2	0	154	6
y15	1	0	154	6
y16	1	0	154	6

Table 5. Initial JSF pilots.

This table identifies the initial set of JSF pilots who have already transitioned to the JSF community. The "transitioned" column defines the number of pilots for each YCS that are in the community when the model starts. The remaining hours and months required for training are also listed.

The "avail_pool" tab (see Table 6) provides information on pilots available to be assigned to the JSF. It lists the number of years that a pilot is available for re-assignment within the community, and sets the starting period for the current assignment.

Pilots available for transition						
YCS	Pilots	When Available		Max Years	Available	
y03	5	tDEC10		8		
y04	21	tDEC10				
y05	29	tDEC10				
y06	25	tDEC10		Training Requirements		
y07	27	tDEC10			Hours	Periods
y08	28	tDEC10		new	217	9
y09	23	tDEC10		exp	154	6
y10	20	tDEC10				
y11	10	tDEC10				
y12	22	tDEC10				
y13	18	tDEC10				
y14	14	tDEC10				
y15	18	tDEC10				
y16	16	tDEC10				

Table 6. Available pilots from legacy platforms.

This table lists the number of pilots in legacy communities that are available for conversion by YCS, during a specified planning period. The maximum duration these pilots will be available for conversion and their training requirements are also listed.

2. Planner Input

Most planner input occurs on tabs 5 through 12. Tabs 5 and 6 provide data on squadron deactivations for F/A-18 Hornets and AV-8B Harriers. Data inputs include the number of pilots by YCS that are available for conversion in each type of squadron, and the period of the planned deactivations (see Table 7). The number of pilots available from each deactivated squadron is derived from the squadron deactivation schedule and factors provided by DCA.

AV-8B Harrier standown schedule						
	Operational Squadrons			FRS (Training) Squadrons		
YCS	Pilots/Sq	Avail		YCS	Pilots/Sq	Avail
y03	0	0		y03	2	0
y04	2	0		y04	3	0
y05	3	0		y05	2	0
y06	2	2		y06	2	0
y07	2	1		y07	2	0
y08	2	1		y08	2	1
y09	2	1		y09	2	2
y10	1	1		y10	2	2
y11	2	2		y11	1	1
y12	1	1		y12	1	1
y13	1	1		y13	1	1
y14	0	0		y14	1	1
y15	0	0		y15	0	0
y16	1	1		y16	1	1
	19	11			22	10
	Standdowns				Standdowns	
	Period	Squadrons			Period	Squadrons
	tJAN14	1			tJAN19	1
	tJAN17	1				
	tJAN18	1				
	tJAN19	1				
	tJAN20	2				
	tJAN21	1				

Table 7. Squadron deactivation schedule.

This table details the deactivation schedule for AV-8B Harrier squadrons. The first three columns identify, by YCS, the number of pilots assigned to a squadron and the number that will be available for conversion at deactivation. The second three columns provide the same information for the Harrier training squadron. The bottom tables identify the period of the planning horizon that squadrons are scheduled to deactivate and the number of squadrons that will do so during that period.

Tab 8, "nn," lists the number of new accessions that are available during each period of the planning horizon (nn_t in the formulation). Aviation Training Branch of Training and Education Command provides this data, which is the number of new pilots expected to complete advanced flight training for jets.

Tabs 9 thru 11 detail the requirements for 10, 16, and 20 plane squadrons over the planning horizon. This data is derived from the squadron activation schedule and the T/O (see Table 8).

10-Plane squadron standup schedule

Period	Squadrons	Pilot requirements	Experience	Rank	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
tAPR12	1	RFO (Ready for Operation)	exp	capt	1	1	1	2	2	2	2	2	2	2	2	2
tSEP13	1	4	exp	major	1	1	1	1	1	1	1	1	1	1	1	1
tJAN15	1	periods prior to standup the	exp	ltcol	0	0	0	0	0	0	0	0	0	0	0	0
tMAY15	1	following pilots must be available	new	capt	4	4	4	3	3	3	3	3	3	3	3	3
tNOV15	1		new	major	1	1	1	1	1	1	1	1	1	1	1	1
tAPR16	1		new	ltcol	1	1	1	1	1	1	1	1	1	1	1	1
tMAY18	1															
tDEC18	1	IOC (Initial Operation Capability)	exp	capt	0	0	0	2	2	2	2	2	2	2	2	2
tMAY19	1	10	exp	major	0	0	0	0	0	0	0	0	0	0	0	0
tSEP19	1	periods after standup the following	exp	ltcol	0	0	0	0	0	0	0	0	0	0	0	0
tJAN20	1	additional pilots must be available	new	capt	5	5	5	3	3	3	3	3	3	3	3	3
tAPR20	1		new	major	2	2	2	2	2	2	2	2	2	2	2	2
tAUG20	1		new	ltcol	0	0	0	0	0	0	0	0	0	0	0	0
tNOV20	1															
tFEB21	1	Full complement	exp	capt	0	0	0	0	0	0	0	0	0	0	0	0
tJUL21	1	2	exp	major	0	0	0	0	0	0	0	0	0	0	0	0
tOCT21	1	periods after IOC the following	exp	ltcol	0	0	0	0	0	0	0	0	0	0	0	0
tJAN22	1	additional pilots must be available	new	capt	2	2	2	2	2	2	2	2	2	2	2	2
tJUN22	1		new	major	0	0	0	0	0	0	0	0	0	0	0	0
tSEP22	1		new	ltcol	0	0	0	0	0	0	0	0	0	0	0	0

Rank	Year FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
capt	1	1	1	2	2	2	2	2	2	2	2	2
major	1	1	1	1	1	1	1	1	1	1	1	1
ltcol	0	0	0	0	0	0	0	0	0	0	0	0
capt	4	4	4	3	3	3	3	3	3	3	3	3
major	1	1	1	1	1	1	1	1	1	1	1	1
ltcol	1	1	1	1	1	1	1	1	1	1	1	1

Table 8. Squadron requirements.

This table details the requirements for each 10-plane JSF squadron. The first two columns provide the month of the planning horizon that squadrons will activate and the number of squadrons that will do so during that period. "Pilot requirements" identify periods of time that pilots are required before and after squadron activation. For example, RFO = 4 identifies that pilots required at RFO are assigned 4 months prior to the squadron activation, and IOC = 10 means that pilots required for IOC are assigned 10 months after squadron activation. The right side of the table details the number of pilots in each fiscal year (FY) that are required for each existing JSF squadron, by experience and rank.

The last user input tab (see Table 9), "fh," is derived from the aircraft delivery schedule and lists the number planes delivered and the number flight-hours available for pilot training during each period of the planning horizon (used to calculate fh_t). A percentage of the available flight-hours will be subtracted from each aircraft for losses that arise from unscheduled maintenance, weather, etc.

Aircraft Arrivals			
Period	F-35 aircraft	training hours/aircraft	overhead
tDEC10	1	25	27.75%
tJAN11	2	25	27.75%
tFEB11	1	25	27.75%
tMAR11	2	25	27.75%
tAPR11	2	25	27.75%
tJUN11	1	25	27.75%
tOCT11	1	25	27.75%
tDEC11	1	25	27.75%
tJAN12	2	30	27.75%
tMAR12	1	30	27.75%
tMAY12	1	30	27.75%
tJAN13	3	35	27.75%
tFEB13	1	35	27.75%
tMAR13	1	35	27.75%
tAPR13	1	35	27.75%
tMAY13	1	35	27.75%
tJUN13	1	35	27.75%
tJUL13	1	35	27.75%
tAUG13	1	35	27.75%

Table 9. Aircraft delivery schedule and available flight-hours.

Partial list of flight-hours per aircraft delivered during each planning period. The actual hours available for training each month consists of training hours minus the overhead percentage.

After completing changes to the planner input sheets, a macro generates six comma separated value (csv) files that are used as input to GAMS. Using the "Export and Solve" button, the csv files are submitted to GAMS. GAMS returns a solution in six additional csv files that are added to the workbook.

B. RESULTS

For input data described above, each successive period is discounted by 1/100 of a percent, which identifies that filling requirements in the current period is more valued than postponing those fills to later periods. Penalties of 1, 1.5, and 2.5 amplify costs for shortages of Captains, Majors, and Lieutenant Colonels, respectively, in a period. Penalties for excess Captains, Majors, and Lieutenant Colonels, is 1/20 the penalty for a shortage. Additional penalties of 1/100 and 1/500 are associated with rank substitutions and exceeding available hour limits.

MCPCAT generates a solution in under seven minutes. It takes Excel one minute to create and export the csv files to GAMS. GAMS solves in four minutes and uses another two min to create output reports in the form of csv files and return the solution to the workbook. In this instance, 40,390 career paths are generated from which pilots for accession or conversion are prescribed. Table 10 displays the aggregate prescription for pilots by YCS for FY2011 thru FY2022.

YCS	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
y03	0	0	5	12	12	10	8	8	11	8	8	0
y04	15	0	0	0	0	0	0	0	0	0	0	0
y05	9	0	0	0	0	0	0	0	0	0	0	0
y06	0	0	0	6	0	0	8	0	4	4	2	2
y07	0	0	0	6	0	0	1	0	2	2	1	1
y08	0	2	5	0	0	0	0	0	3	4	6	1
y09	1	0	7	0	0	0	0	0	4	2	8	1
y10	0	0	0	2	0	5	0	0	4	2	1	1
y11	0	0	3	7	4	0	0	0	5	4	5	9
y12	1	3	3	1	0	0	0	0	3	5	4	1
y13	1	3	0	0	3	0	0	0	3	5	1	1
y14	2	0	0	0	0	0	0	0	1	0	0	0
y15	1	0	0	0	0	0	0	0	0	0	0	0
y16	1	0	0	0	0	4	3	0	3	2	1	1
y17	0	0	0	0	0	0	0	0	0	0	0	0
y18	0	0	0	0	0	0	0	0	0	0	0	0
y19	0	0	0	0	0	0	0	0	0	0	0	0
y20	0	0	0	0	0	0	0	0	0	0	0	0
y21	0	0	0	0	0	0	0	0	0	0	0	0
y22	0	0	0	0	0	0	0	0	0	0	0	0
sum for FY	31	8	23	34	19	19	20	8	43	38	37	18

Table 10. Prescribed accessions and conversions for FY2011 thru FY2022.

The table lists the number of pilots by YCS (row) the model prescribes for selection in the FY identified in the column heading.

GAMS generates six csv files that contain:

- The number of pilots for accessions and/or conversions by YCS. An additional column provides the quantity of pilots that are not converted (surplus).
- An aggregate of the number of pilots prescribed for conversion by YCS in each FY of the planning horizon.
- The number of pilots for accession and the number of surplus for each FY of the planning horizon.
- The career paths of each selection for accession and/or conversion.
- The percentage of fill and surplus for each rank and experience level, in each month of the planning horizon.
- The number of training hours used in each month of the planning horizon.

Figures 6 and 7 graphically depict the pilot requirement against the number of pilots available to fill flying billets. The Lieutenant Colonel (Figure 6, left) and Major (Figure 6, right) requirements are easily filled and sometimes overfilled, whereas the requirement for Captains (Figure 7) falls short beginning in FY2012 and remains deficient of the billet requirements throughout the planning horizon. The current DCA plan does not detail the rank breakdown of selected pilots, but the model results show that with the current selection policy, there will be a significant shortage of Captains throughout the transition.

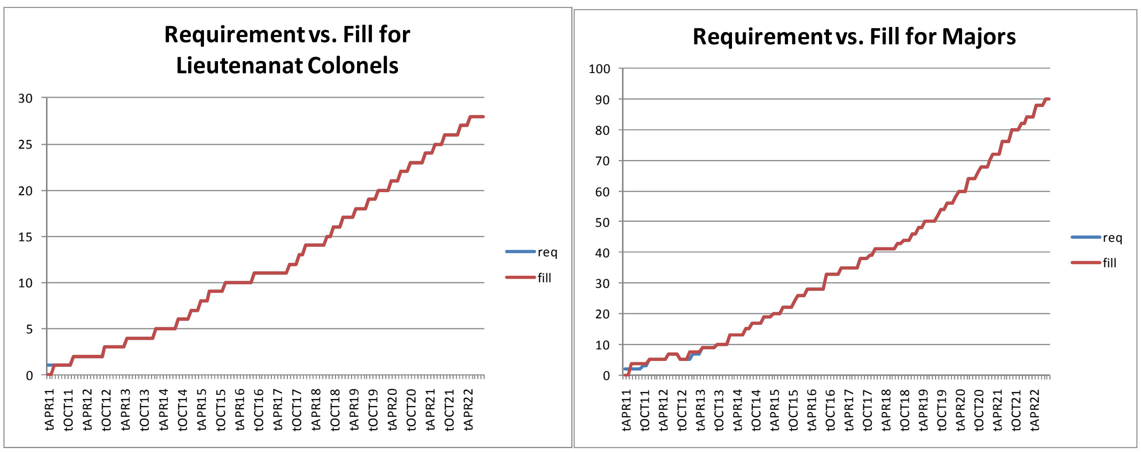


Figure 6. Billet requirements vs. billets filled for Lieutenant Colonels (left) and Majors (right).

This figure compares the billet requirements against the billets filled for Lieutenant Colonels and Majors over the transition horizon from FY2011 through FY2022. The graph shows that these billets are effectively filled throughout the planning horizon.

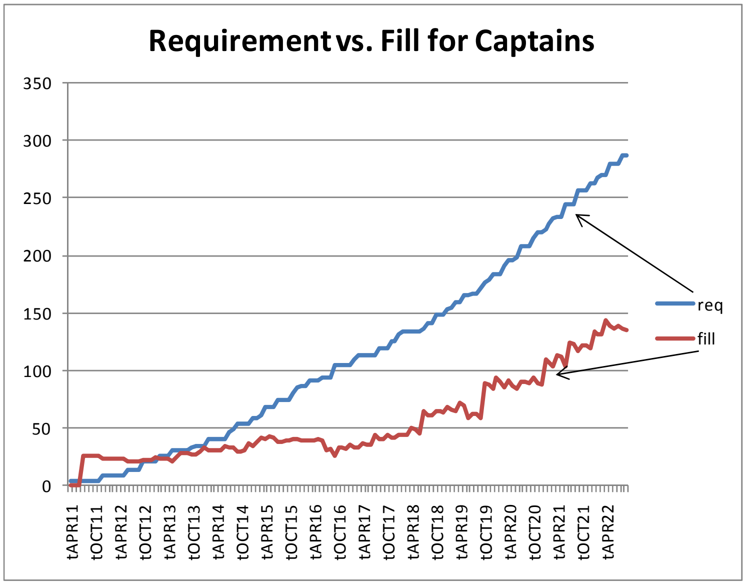


Figure 7. Billet requirements vs. billets filled for Captains.
Graphical comparison of the billet requirements for Captains vs. the number of billets filled over the transition horizon from FY2011 thru FY2022. The graph shows our optimization cannot bring in or convert enough Captains to fill the squadron activation requirements.

Figure 10 displays the number of training flight-hours available versus the number of hours required for pilot conversions. Both the MCPAT estimate of available hours and the DCA planned estimate are displayed, along with the training hour requirement for pilot conversions. The graph shows that a significant backlog of training hours accumulates during the first two years, climaxing at a 4,388 hour shortage in flight training in May 2011. This deficiency is eliminated by May 2013 as additional aircraft are delivered. Additional training hour backlogs occur in FY2019, FY2020, and FY2021 due to multiple squadrons standing up during these FYs.

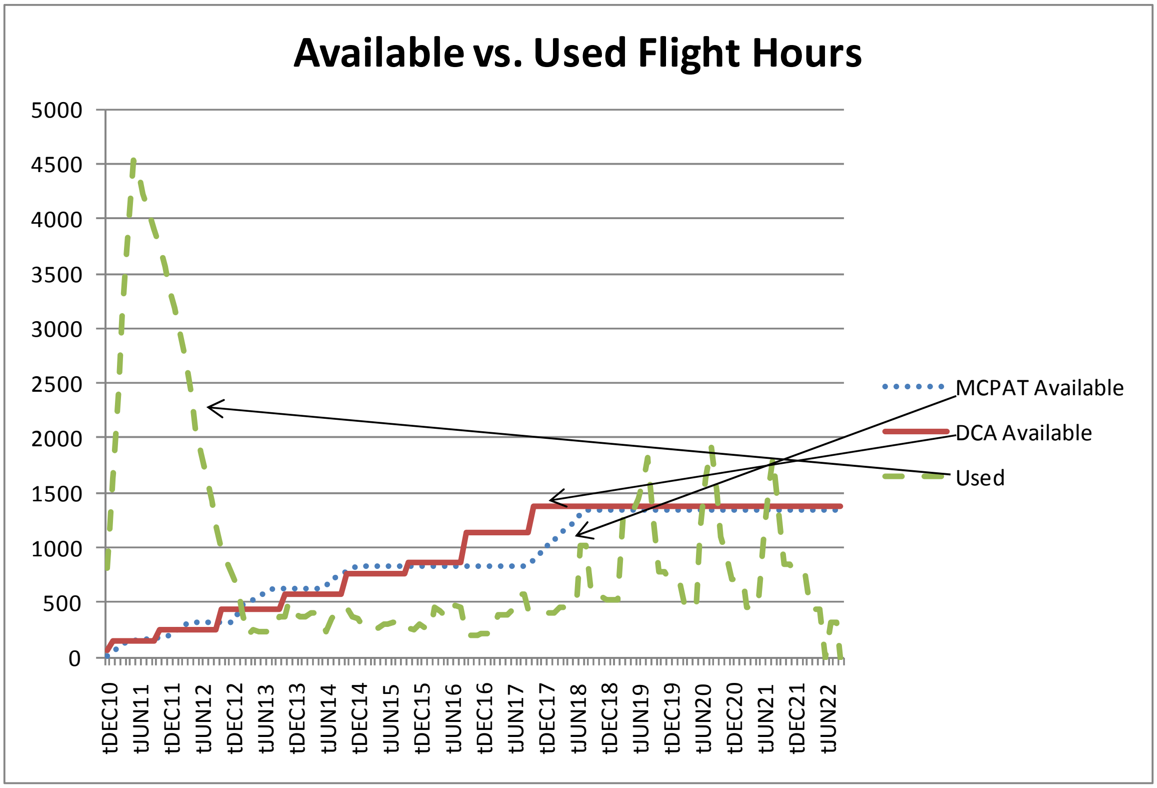


Figure 8. Flight-hour comparison.

Graphical comparison of MCPAT and DCA available training hours against the training hours required for pilot conversions. The available hours estimates for the model and the DCA plan are comparable. A significant backlog of training flight-hours is accumulated over the first two years and is eliminated by May 2013 as additional aircraft are delivered to the FRS.

The current DCA plan accumulates a backlog of flight training hours that climaxes at 3,878 hours in FY2016, decreases to 183 hours in FY2018, then climbs to 8,260 hours in FY2021. The DCA estimated backlog of flight training hours accumulates a total of 41,484 hours that are never eliminated during the planning horizon.

The MCPAT solution closely resembles the current DCA plan in the number of pilots that are selected for accession or conversion during the periods of transition, but differs greatly in the estimate of the accumulation of training hours required for transitioning pilots. As previously stated, the DCA plan does not identify the rank breakdown of the pilots selected, but the model shows that there is a significant shortage in the number of Captains that are prescribed for accession or conversion.

C. ANALYSIS

Two areas of interest were identified during the analysis of the original problem: the shortage of Captains prescribed for accession or conversion and the significant backlog of training flight-hours accumulated over the planning horizon. To analyze these two issues, several alternative policies are introduced for evaluation. The training time backlog is analyzed by reducing the training time requirements and altering the current aircraft delivery schedule to provide more aircraft to the FRS earlier in the planning horizon. The shortage of Captains is analyzed by allowing one-up and one-down rank substitutions, and increasing the number of new accessions available.

1. Reduction of Time to Train

To evaluate the effects of reduced training time, the training requirements were incrementally decreased by 10, 20 and 30 percent. Figure 11 shows a comparison of the available training hours and the hours required for training. The training plan is currently being developed at VMFAT 501, and will certainly undergo revisions as the initial pilots flow through the program.

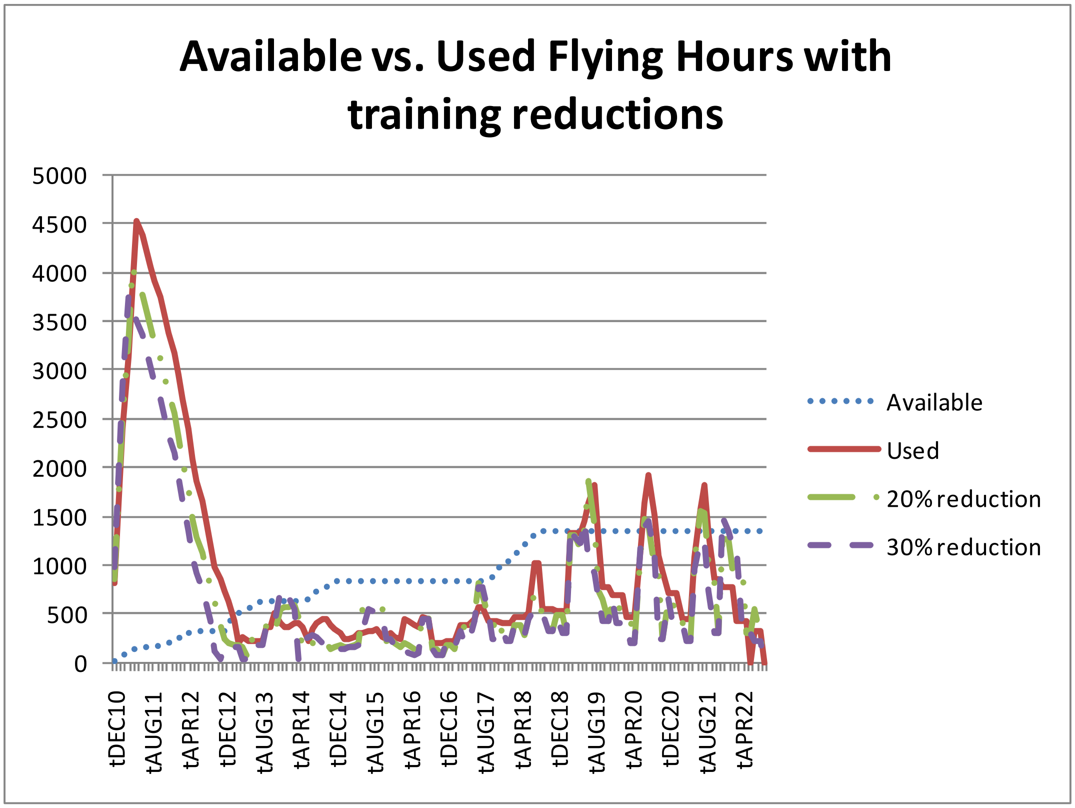


Figure 9. Flight-hour comparison with training reductions.

The graph compares the number of flight-hours available for training to the number of flight-hours needed as training time is incrementally reduced. The original solution is overlaid by results from 20 and 30 percent reductions in the time to train requirement. The training backlog is never eliminated, but a 30 percent reduction in required training time reduces the maximum backlog to 3,492 hours from 4,388, and eliminates the backlog by October 2012 vice May 2013.

Although a backlog of training hours is created in every scenario evaluated, it is clear that any reduction in the training hour requirement reduces the maximum backlog, and eliminates the entire backlog faster.

2. Reallocate Aircraft to FRS

The second alternative evaluated reallocating aircraft to the FRS earlier in the planning horizon to create more hours for training. According to the current delivery schedule, VMFAT 501 will receive one aircraft in 2010, nine in 2011, and the remaining 10 in 2013. In 2012, VMAT 332, the first operational squadron will receive its 10 aircraft.

To evaluate the effects of allocating additional aircraft to the FRS, aircraft deliveries to VMAT 332 are redistributed to VMFAT 501 on the currently-prescribed schedule. The aircraft reallocation helps eliminate the existing backlog by December 2012 vice May 2013. The same backlog elimination is also achieved from a 20 percent reduction in the current training hour requirement. Though there is some benefit to eliminating the backlog earlier, the tradeoffs would require that the first operational squadron activation be delayed one year.

3. Rank Substitution

The integer linear optimization allows for one-up substitution, but is not designed for one-down substitution. To simulate this using the spreadsheet, all requirements for Captains are changed to requirements for Majors. This way shortages in available Lieutenant Colonels will use available Majors, and shortages in available Majors will use available Captains.

YCS	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
y03	0	0	8	5	5	0	0	0	0	0	0	0
y04	0	0	0	0	0	0	0	0	0	0	0	0
y05	0	0	0	0	0	0	0	0	0	0	0	0
y06	0	0	13	0	0	0	0	0	0	0	0	0
y07	0	0	0	7	0	0	0	0	2	0	0	0
y08	0	0	1	5	1	0	0	0	3	0	0	0
y09	5	1	1	0	0	0	0	0	8	3	1	0
y10	0	4	3	0	0	0	0	0	4	6	4	1
y11	0	6	5	2	0	0	0	0	5	10	8	2
y12	1	1	6	0	0	0	0	0	3	2	8	1
y13	1	3	0	2	0	0	0	0	3	6	2	3
y14	2	0	0	0	0	0	0	0	1	0	0	0
y15	1	0	0	0	0	0	0	0	0	0	0	0
y16	1	2	2	2	0	0	0	0	3	3	5	1
y17	0	0	0	0	0	0	0	0	0	0	0	0
y18	0	0	0	0	0	0	0	0	0	0	0	0
y19	0	0	0	0	0	0	0	0	0	0	0	0
y20	0	0	0	0	0	0	0	0	0	0	0	0
y21	0	0	0	0	0	0	0	0	0	0	0	0
y22	0	0	0	0	0	0	0	0	0	0	0	0
sum for FY	11	17	39	23	6	0	0	0	32	30	28	8

Table 11. Prescribed accessions and conversions allowing one-up and one-down rank substitutions.

This table provides an aggregation of prescribed solution for accession and conversion allowing one-up and one-down rank substitution from FY2011 thru FY2022.The table list the number of pilots by YCS (row) that the model prescribes for selection in the FY identified in the column heading.

Table 11 shows the aggregation, by YCS, of the pilots prescribed for accession or conversion in each FY of the planning horizon, allowing one-up and one-down rank substitution. Allowing rank substitution successfully meets all billet requirements, as seen in Figure 12, but creates other issues. From table 11, there are three consecutive years (FY16 thru FY18) where no pilots were selected for accession or conversion at all, and very few new accessions were selected over the entire horizon.

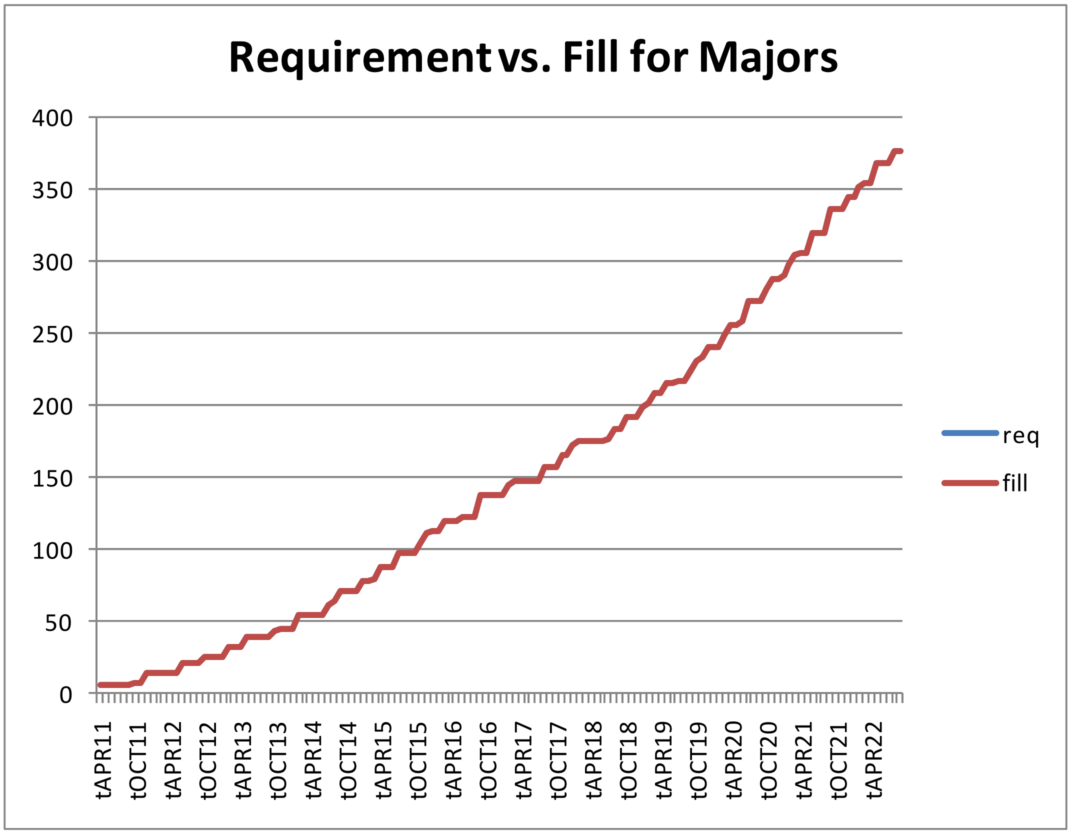


Figure 10. Billet requirements vs. billets filled for combined Captains and Majors. The graph shows that all billets are effectively filled throughout the planning horizon, for combined Captain and Major requirements. The graph for Lieutenant Colonel fills (not displayed) shows a similar result.

During the same three-year period, there is a significant drop in training flight hours use as shown in Figure 14. On the other hand, allowing rank substitution reduces the maximum backlog to 538 hours, which is eliminated by September 2011. Although feasible, this solution will not retain the hierarchical structure desired, and could lead to a 'top heavy' organization because very few new accessions are selected to fill the Captain billets which make up between 70 and 75 percent of squadron billet requirements.

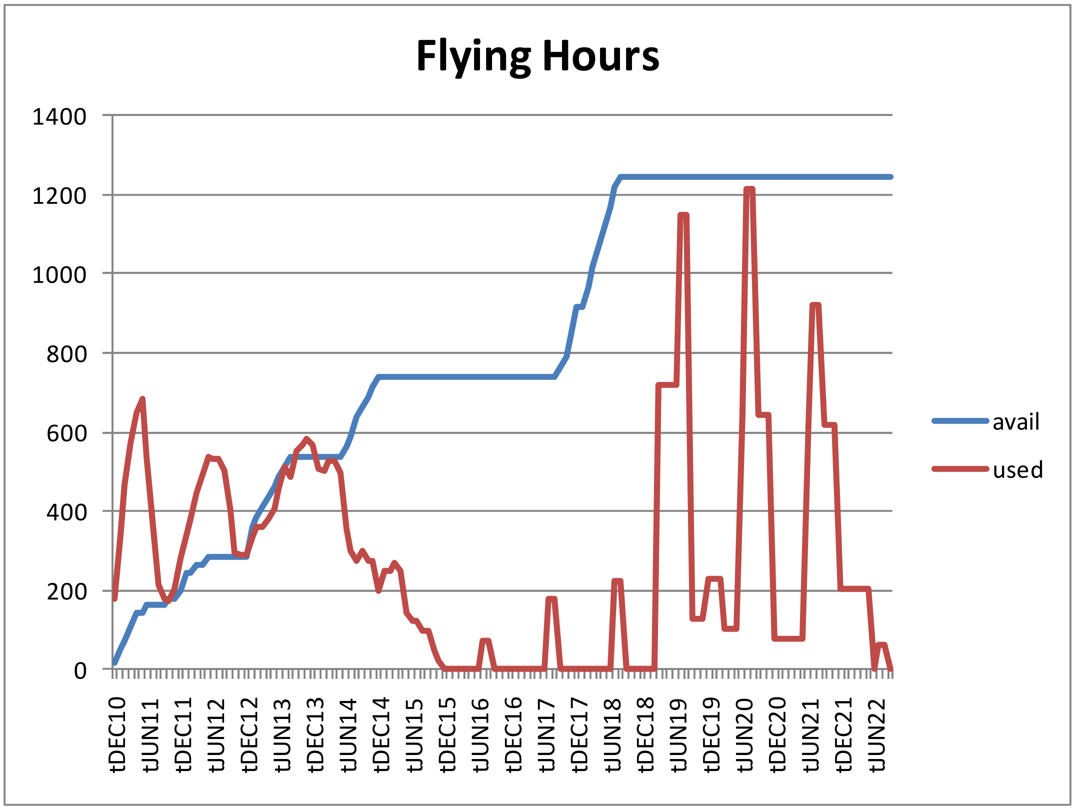


Figure 11. Flight-hour comparison while allowing one-up and one-down rank substitutions.

The graph compares the number of flight-hours available for training to the number of flight-hours needed when rank substitution is allowed. Interestingly, the maximum training hour backlog is reduced and eliminated earlier than when one-down rank substitutions are disallowed.

4. Increase New Accessions

To increase the number of Captain billets filled, the number of new accessions available for assignment is increased above what is currently planned. Table 12 details the prescribed assignment of pilots by YCS for each FY of the planning horizon. This solution prescribes significantly larger numbers of new pilots, and is the only solution from those analyzed that is able to fulfill all billet requirements, while maintaining the desired rank distribution of the organization.

YCS	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
y03	0	0	10	38	40	41	46	67	47	30	51	0
y04	6	0	0	0	0	0	0	0	0	0	0	0
y05	0	0	0	0	0	0	0	0	0	0	0	0
y06	3	10	0	0	0	0	0	0	8	14	2	2
y07	0	6	1	0	0	0	0	0	2	2	7	1
y08	0	0	6	0	0	0	0	0	3	2	8	1
y09	1	0	6	0	0	0	0	0	4	2	8	1
y10	0	0	0	0	0	7	0	0	4	2	1	1
y11	0	2	0	4	2	3	2	0	5	6	2	2
y12	1	2	4	0	1	0	0	0	3	2	7	1
y13	2	0	1	4	1	0	0	0	4	2	2	5
y14	2	0	0	0	0	0	0	0	1	0	0	0
y15	1	0	0	0	0	0	0	0	0	0	0	0
y16	1	0	6	0	0	0	0	0	3	0	9	2
y17	0	0	0	0	0	0	0	0	0	0	0	0
y18	0	0	0	0	0	0	0	0	0	0	0	0
y19	0	0	0	0	0	0	0	0	0	0	0	0
y20	0	0	0	0	0	0	0	0	0	0	0	0
y21	0	0	0	0	0	0	0	0	0	0	0	0
y22	0	0	0	0	0	0	0	0	0	0	0	0
sum for FY	17	20	34	46	44	51	48	67	84	62	97	16

Table 12. Prescribed accessions and conversions with increased new accession availability.

This table provides an aggregation by fiscal year of prescribed accessions and conversions with increased availability of new accessions from FY2011 thru FY2022. From the first row, "y03" it is evident that the number of new accessions prescribed is significantly increased in comparison to the other alternatives analyzed.

Figure 12 shows the comparisons of billet requirements to available pilots for Captains and Majors over the planning horizon.

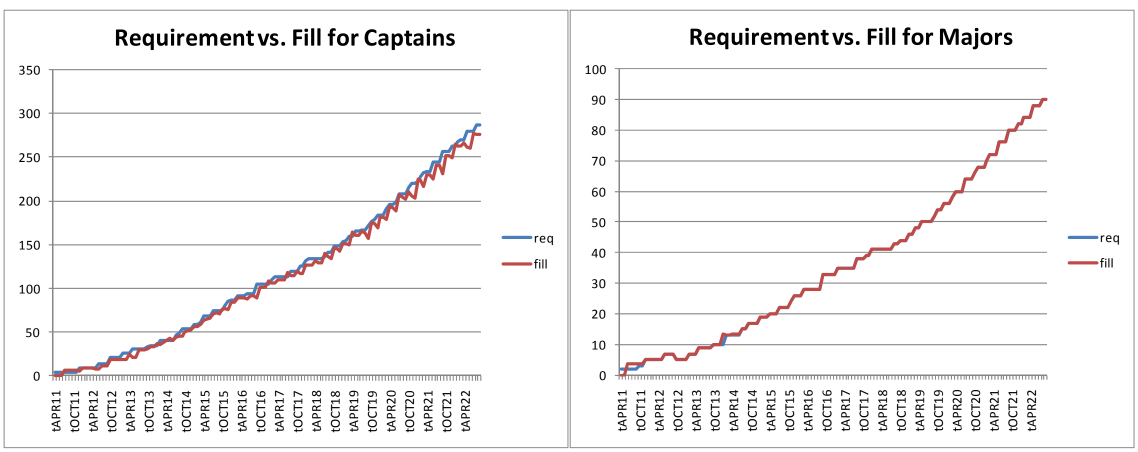


Figure 12. Requirements vs. billets filled for Captains (left) and Majors (right) with increased availability of new accessions.

Graphical comparison of billet requirements for Captains and Majors versus the number of billets filled over the transition horizon from FY2011 through FY2022. The graph shows that all Captain billets are effectively filled throughout the planning horizon given a significant increase in the number of new accessions. The graph for Major billets shows that they are also effectively filled. Lieutenant Colonel fills show a similar result.

Figure 17 shows the comparison of available flight-hours to the number required to train converting pilots. In comparison to the initial solution, bringing in new accessions creates a maximum backlog of 1,487 hours vice 4,388, and the back log is eliminated by March 2013 versus May 2013.

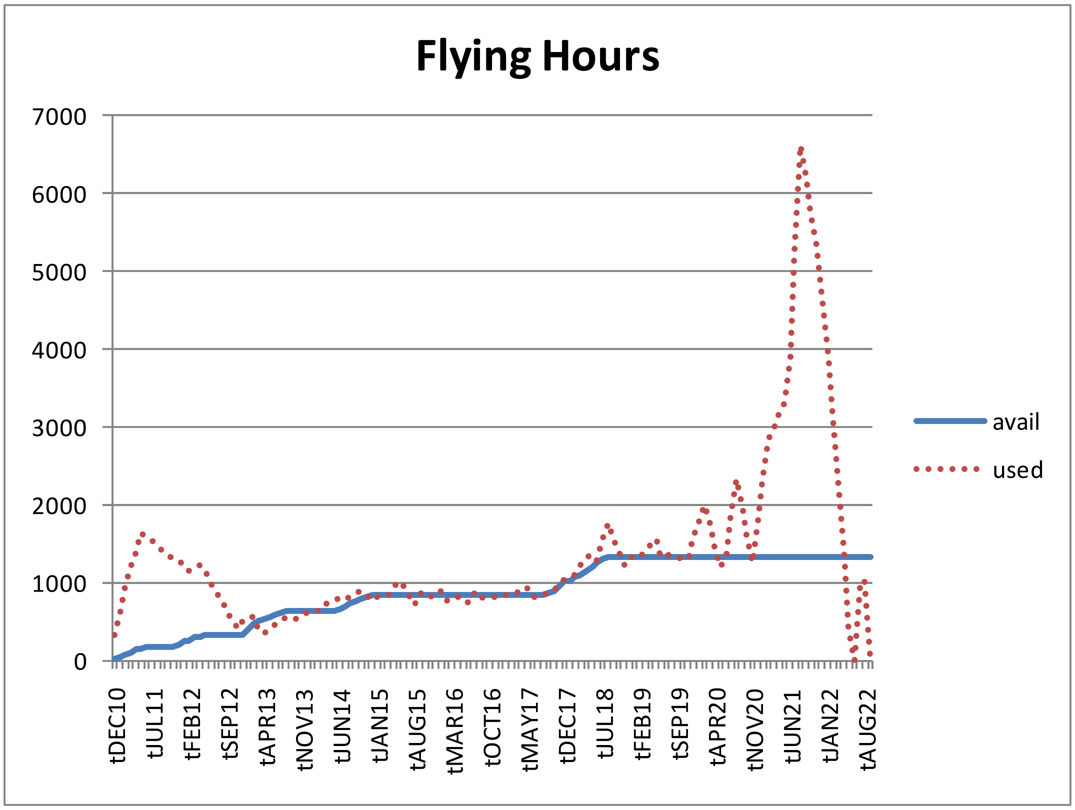


Figure 13. Flight-hour comparison with increased new accessions.

The graph compares the number of flight-hours available for training to the number of flight-hours needed when significant numbers of new accession are prescribed.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis presents the Marine Corps Pilot Conversion Analysis Tool that uses an integer linear program to prescribe pilots for accession and/or conversion to the JSF based on rank, YCS, and experience. This tool will assist DCA convened boards in selecting the appropriate mix of pilots for transition or conversion training through evaluation of current and alternative policies. DCA's goal is to select the right distribution of officers from legacy communities and new accessions to fill the manning requirements of new JSF squadrons while maintaining the traditional hierarchical structure of Marine Corps squadrons, and maintaining the capabilities of legacy platforms during the transition horizon. A reasonable replication of the current pilot population is generated by enumerating combinations of career assignments over the 12-year planning horizon. The integer linear program selects those career paths that best satisfy the requirements for pilots as new squadrons activate according to scheduled aircraft deliveries.

Analysis conducted in this thesis shows that the current DCA plan meets the total pilot accession and conversion requirement based on the squadron activation schedule, but does not select sufficient junior-ranking officers to maintain the hierarchical structure desired in the JSF community. Additionally, the ability to convert or bring in new pilots is hindered, initially, by the lack of available flight hours for training.

Analysis of several alternatives reveals that our solution is improved most by increasing the number of new accessions available for assignment to the JSF and selecting more junior-ranking pilots for conversion. These recommendations provide the best pilot-to-billet matches and create the smallest flight hour backlog.

B. RECOMMENDATIONS

This thesis recommends that DCA:

- Increase the number of new accessions into the JSF community.
- Direct selection boards to consider more junior-ranking officers for conversion.
- Evaluate alternatives to reduce the current pilot training requirements at the FRS.
- Implement MCPCAT to evaluate pilot transition and/or conversion policy.

Time constraints restricted the number of alternatives that were evaluated in this thesis. Recommendations for future work on this subject include:

- Evaluate the effects of delays in aircraft deliveries. Does this provide any relief to the FRS flight hour backlog?
- Evaluate the effects of a less aggressive squadron activation schedule. Does an extended activation schedule reduce the flight hour requirement at the FRS?

Further work on the subject is already planned to include prescriptions for aviation ground officers and enlisted maintainers and ground crews. Other areas of consideration that could benefit this work include an analysis of the current pilot training program and alternatives that reduce the flight hour requirement for initial qualifications and requalifications.

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